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RECEIVED
AUG 1 6 2004
Federal Communications Commission
Office of the Secretary

BY HAND DELIVERY
Ms. Marlene Dortch
Secretary
Federal Communications Commission
445 12th St. SW
Washington, DC 20554

Attention: Julius Knapp, OET

Re: Wavebounce GPR Waiver

Dear Ms. Dortch:

This supplement to the waiver request filed by Wavebounce and GPR Service Providers on July 6, 2004 addresses certain concerns or issues raised by the staff at a recent conference. The unique challenges posed by highway surveying are critical to understanding the problem posed by the new GPR limits: roadbeds are composed of aggregate material in layers which can become corrupted below the surface. A useful surveying device must therefore address (1) the material of which highways are composed, (2) the layering of the undersurface, and (3) the need to survey at relatively high speeds. This confluence of three unusual factors is what has created the need for a waiver of the general rule to deal with them.

1. Attachment 1 explains the straightforward relationship between the power needed to obtain useful information at highway speeds and the limits imposed by the FCC's rules. The memo explains why a relatively high PRF *and* relatively high energy per pulse are necessary if the benefits of GPR for highway surveys are to be realized. The Wavebounce proposal strikes a compromise between PRF and energy per pulse in order to remain within normal Part 15 limits (500 microvolts/meter at frequencies above 960 MHz) while meeting the standards established by the Texas Transportation Institute for useful GPR data. Anything less than that effectively negates the utility of GPR for highway applications.

2. Some confusion may have arisen from the suggestion by another waiver applicant, RSI, that highway speeds of 30 MPH were possible without a waiver. Upon inquiry, it has been explained

that RSI meant that highways speeds of 30 MPH are possible using *grandfathered* horn antenna GPR equipment. As we understand it, RSI is seeking a waiver to permit the grandfathered horn antenna equipment to operate at a higher PRF (and thus, effectively, a higher power) so as to permit useful highway scans at up to 50 MPH. The Wavebounce proposal is similarly designed to permit operation at those speeds. Under the present Part 15 limits on GPRs, all available feedback consistently reports that surveys undertaken at speeds above 4-5 MPH provide insufficient scan data to be useful for any purpose.

3. The frequency of the Wavebounce system is centered between 960 and 1500 MHz. Because the "peak" is relatively low in relation to the overall frequency curve, the design could conceivably be tweaked to "center" the peak below 960 MHz or above 1610, but the overall emissions in the 960-1610 band would remain relatively unchanged. The original petition explains that operation in this frequency band is essential because, at frequencies above 3.1 GHz, tests show that the scattering effect from typical highway aggregate material becomes unacceptable. At frequencies below 960, sufficient resolution of the different layers of highway material is impossible. Sacrificing resolution by a factor of two by doubling the pulse width was seen early on as an option for highway radar to survive the new emission limits. However, any practical implementation of this idea to meet the new Part 15 limits degrades resolution far more than a factor of two and results in a device which provides useless data.

For example, GPR velocity in asphalt is typically 5"/ns; considering the round trip travel time of the GPR signal in an asphalt pavement layer (as observed in the GPR record) the velocity is 2.5" per nanosecond. Based on this velocity, the use of a 1 GHz GPR system (with a 1 ns. nominal pulse width) allows resolution (*i.e.*, adequate separation of reflections) of pavement layers as thin as 1.5-2.0". Typically asphalt pavement layers are placed between 2-3". Most overlays are between 2 and 3 inches thick, and for many pavements, the total surface thickness is 3" or less. Increasing the pulse width by a factor of 2 (*i.e.*, lowering the center frequency by a factor of 2) will limit the resolution to 3 to 4 inches. This means that at least 50% of the pavement in the U.S. (those with layers less that 3 inches)could not be surveyed with such a limitation.

4. Wavebounce and the GPR Service Providers considered the possibility of a "black box" type device which would record the location and time of operation of the units in case any question arose about their operations. Such a device would be technically feasible at an added cost, but, as we considered the matter, probably duplicative. The data gathered from GPR surveys is always retained for some period of time simply for the actual purpose for which the survey was commissioned (to determine whether and how urgently repairs of highways, bridges or tunnels are needed). Typically the users of GPR are, directly or indirectly, transportation departments or other transportation authorities. We believe that these entities would not object to retaining the gathered data for some period of time, perhaps 6 months, to ensure its availability if a question arose about any aspect of operations. No "black box" would be necessary since the survey itself is designed to gather and record the information

which would presumably go into the box. As long as this data was available for scrutiny by the Commission or NTIA on request, the information would be adequately preserved.

5. One further clarification may be in order. The subject of airport surveys came up briefly at the meeting. It had been assumed that the survey of a runway a mile or so long could be done very quickly even at 5 MPH and therefore there was no need for high speed GPR use in that context. It appears, however, that many runways are longer than a mile and that surveying a single runway involves 30 to 40 passes over the runway to cover the entire pavement. These surveys are typically done at night when air traffic is low or nil to avoid disruption of normal operations. At 5 MPH it would take 12-14 hours to survey a single 1.5 mile runway, and most airports have multiple runways. Thus, while runways certainly involve less sheer mileage than normal highways, they also require a higher number of passes to get complete data.

Respectfully submitted,

WAVEBOUNCE and
GPR SERVICE PROVIDERS

By Donald J. Evans
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DJE:deb

Enclosures

cc: John Reed, OET

Why normal Part 15 emissions limits are required for useful highway survey radars

The parameters leading to the average radar power are rather straightforward to describe. For a given bandwidth and antenna geometry, the power presented to the transmit antenna is proportional to the measured Equivalent Isotropic Radiated Power (EIRP, actually a spectral density commonly measured in dBm/MHz). In the relations shown below, the arrow indicates that the product on the left produces (i.e., is proportional to) a given EIRP.

$$[{}^{energy}/_{trace}] \times {}^{trace}/_{sec} \Rightarrow EIRP \qquad (1)$$

Relation (1) shows that the product of the energy per trace (a trace is an output data record) multiplied by the number of traces per second produces a given EIRP. For example, if one factor is doubled and the other is halved, the resulting EIRP remains unchanged. Note that the "trace" parameter cancels, leaving energy/sec which is, by definition, the unit of power. A minimum energy per trace is required to produce a signal with the required fidelity (signal to noise ratio) while a minimum number of traces per second is required in order to survey a roadbed at highway speeds. As mentioned in the original petition, the required energy/trace for non-contact radars is significantly higher than that needed for ground coupled units due to its less efficient coupling into and out of the pavement. In addition, the number of traces/sec must be much higher in order to survey at highway speeds. The end result is that the EIRP required to produce the data quality and quantity required for highway surveys (and pass performance standards, such as those established by the Texas Transportation Institute, TTI) amounts to the normal Part 15 limits.

Relation (1) can be stated differently in order to point out how the Pulse Repetition Frequency (PRF) contributes to EIRP. Note the bracketed energy/trace can be rewritten to produce an equivalent relation shown in (2):

$$[{}^{energy}/_{pulse} \times {}^{pulses}/_{trace}] \times {}^{trace}/_{sec} \Rightarrow EIRP \qquad (2)$$

where pulses/trace represents the number of radar pulses used to represent a single output trace or record. The energy per pulse is limited by the technology used. The Wavebounce pulser design produces approximately 2×10^{-10} joules/pulse and is somewhat lower than other designs with less favorable wave shapes. Wavebounce finds that a low energy pulse produces a cleaner signal, i.e., with less spurious signals which would work to mask signals from very closely spaced layers. Relation (2) can be regrouped to produce an equivalent relation (3):

$${}^{energy}/_{pulse} \times [{}^{pulses}/_{trace} \times {}^{trace}/_{sec}] \Rightarrow EIRP \qquad (3)$$

Note that in the bracketed term "trace" cancels, leaving pulses/sec which is the unit describing PRF. Thus (3) can be rewritten as:

$${}^{energy}/_{pulse} \times [PRF] \Rightarrow EIRP \qquad (4)$$

Here we see that for a given value of energy/pulse, there will be a maximum PRF which keeps the unit below the normal Part 15 emissions limit. For the Wavebounce radar, this PRF limit is around 10 MHz. A common PRF for the grandfathered non-contact highway survey radars is 5 MHz.

The new rules lower the EIRP limit by a factor of about 250 (24dB) at frequencies just above 0.96GHz. This is very close to the peak of the very wide band of frequencies required for inspection of aggregate layers. A radar operating at the normal Part 15 limit can be made to conform to the new limit by lowering the product of the two factors on the left side of relation (1) by 250. At one extreme, the energy per trace could be lowered by a factor of 250 leaving the number of traces/sec figure unchanged. This low energy per trace results in a waveform in which pavement layer interfaces are too noisy to provide useful data. At the other extreme, the energy/trace is unchanged but the trace rate is dropped by a factor of 250, giving far too few traces/sec to be useful while moving at highway speeds. All compromise solutions between these extremes fail in varying degrees to produce both a useful signal to noise ratio and trace rate adequate for high speed highway surveys. These examples indicate that the normal Part 15 emission limits are required in order to operate useful pavement inspection radars at highway speeds.